Renewable and Sustainable Energy Reviews 13 (2009) 2703–2709

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Energy security vs. climate change: Theoretical framework development and experience in selected EU electricity markets

Konstantinos J. Chalvatzis [a,c,*], Elizabeth Hooper [b,c]

[a] School of Environmental Sciences, University of East Anglia, Norwich, UK
[b] Centre for Competition Policy, University of East Anglia, Norwich, UK
[c] Norwich Business School, University of East Anglia, Norwich, UK

ARTICLE INFO

Article history:
Received 16 June 2009
Accepted 14 July 2009

Keywords:
Energy security
Climate change
Poland
Greece
Germany
United Kingdom

ABSTRACT

Electricity generation in different countries is based on a variety of fuel mixes compromising solid fossil fuels, oil, natural gas, nuclear and renewable energy sources. While in the past, national energy agendas have directed the optimal utilisation of domestic resources as a means to achieve supply security, today's environmental debates are influencing the electricity fuel mix in new directions. In this paper we examine the electricity sectors of Germany, Greece, Poland and the UK in an attempt to identify the policy and technology choices implemented in each country. The country selection is deliberately made to facilitate an extended overview of national agendas, varying domestic energy resources and industrialisation levels but still within the common EU framework. The focus is placed on policies related to two objectives, climate change mitigation and improving electricity supply security. The theoretical framework developed provides the possibility to assess the electricity sector independence at a national level using a multi-parametric analysis of the fuel mix data. Through a comparative assessment of the knowledge gained in different countries the authors provide insights and suggestions that allow for an improved understanding of the trade-offs and synergies that various policy options may introduce.

Contents

1. Introduction

The availability of energy is one of the key factors affecting the well being and smooth functioning of modern societies [1]. Indeed it is plausible to argue that the requirement to secure energy resources has become dominant to the extent that it drives the foreign affairs agenda of countries at all stages of development [2]. As dependence on energy grows, energy carriers with higher flexibility and user-friendly characteristics become more popular. Electricity, being the best example of such an energy carrier, is facing increased demand from all sectors of the economy [3].

The electricity generation mix is based on a variety of fuels; solid fossil fuels, oil, natural gas, nuclear and renewable energy sources. In the past electricity policy in nearly all countries was

* Corresponding author at: School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK. Tel.: +44 7975653868.
E-mail addresses: k.chalvatzis@yahoo.com, k.chalvatzis@uea.ac.uk (K.J. Chalvatzis).

1364-0321/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rser.2009.07.013

based on the optimal utilisation of domestic resources and technology for generating electricity. The result can be observed in the radical variety of fuel mixes existing in different countries; Norway [4,5] relies mostly on hydro, France [6] on its vast nuclear programme and Poland [7] places almost absolute reliance on coal. Apart from these countries that have achieved a considerable degree of energy independence, most others need to import fuel, technology, or often directly electricity, which compromises their supply security.

While in the past, national energy agendas have focussed on supply security which has been achieved using domestic resources, today environmental and market liberalization debates increasingly dominate policy and influence the fuel mix in new directions [8,9]. The threats posed by climate change and local air pollution raise public and political concerns regarding the legitimacy of the continued use of coal and other solid fossil fuels in electricity generation, despite the fact that for most European countries solid fuels are the major indigenous energy resource. Imported natural gas (via pipeline from ex-USSR countries or liquefied from the Middle East and Northern Africa), nuclear energy and renewable sources are increasingly promoted as environmentally friendlier solutions; however, each has an impact on supply dependency. Simultaneously within the context of electricity market liberalization, multinational firms emerge as producers and cross-border trade is providing financial benefits [10] and enjoying legal support [11,12].

These observations are valid for most developed countries but are of crucial importance for the EU not only because of the active promotion of the internal market for electricity among its mix of developed and transitional economies, but also due to its ambition to be recognised as a world leader in climate change abatement initiatives and air pollution measures [13]. The countries examined in the present paper are Germany, Greece, UK and Poland. All but the latter are mature members of the EU with accessions dating back to 1957, 1981, 1973, respectively while Poland joined the EU in 2004. This shared membership background might suggest significant similarities in the energy and climate policies (and performances) of the countries, particularly as the role of pan-EU policy has become stronger. However, reality shows rather the contrary. After this brief introduction this study continues with a description of the methodology adopted. The individual examination of the four countries in Sections 3.1–3.4 while in the fourth section we discuss the results. The fifth and last section contains our conclusions.

2. Methodology

As already mentioned this paper includes a brief analysis of each country studied with primary focus placed on the regulations that serve for the mitigation of climate change. However, not all regulations related to climate change are introduced, but specifically those that are of relevance to the energy supply security of each country. We consider all policies that have a specific impact, regardless if that impact is positive or negative. In order to clarify if the impact of a policy is negative or positive one needs to define supply security.

In the previous decades supply security in the energy sector has been nation centred and based on three major components. First has been the dominant use of indigenous resources which directed the electricity sectors of most European countries to rely to a significant degree on coal. Second has been to acquire technology "know how" in advanced generation methods such as nuclear power. The third pillar has been to gain access to foreign energy resources through investments in their energy sector or even engagement in long-term diplomatic or armed conflicts for disputed resources. More recently, a few parameters have contributed to the evolution of a new reality. In particular the climate change agenda has challenged the continued popularity of coal as a generation fuel, due to its high carbon dioxide emissions. Simultaneously, depletion of indigenous fossil fuel resources has made coal or natural gas in Europe less available than before. Finally competition policy and the development of international trade have allowed increasing cross-border transfer of energy products. Thus supply security in the electricity sector is nowadays achieved by technological and resource diversification, where using a wide range of options is considered to be an optimal strategy. At the same time, it can be argued that exploitation of renewable energy sources makes a positive contribution to the supply security since they are national and may last forever. Finally, energy exchanges either in the form of fuels or in the form electricity are facilitated by grid expansion, increasing interconnector capacity and harmonizing trading and other transmission related rules such as capacity allocation.

Having considered the definition of electricity supply security, this study uses recent data from the Eurostat database to calculate the extent to which each of the examined countries relies on imported resources for its electricity generation. In this context direct electricity imports and are taken into account as well as imports of fuels. The former is calculated as the net result of exports subtracted from imports, yielding net imported electricity. Introducing fuels into the calculation is far more complicated since some fuels used in the electricity sector are partly imported and partly indigenous. Another complication is derived from the fact that some fuels used for electricity generation are used in other sectors of the economy.

The general parameters used in that respect are as follows:
Fuel Fi,j,k where
i refers to the fuel type and takes values shown in Table 1;
j refers to the year studied and takes values shown in Table 2;
k refers to the country studied and takes values shown in Table 3.

If Fi,j,k is imported by $A\%$ then the indigenous contribution of the fuel is $B\% = 100\% - A\%$. For fuels Fi,j,k being exclusively imported, $A\% = 100\%$, $B\% = 0\%$ and their full share in the electricity fuel mix is added in the imported total. For fuels Fi,j,k being exclusively indigenous, $A\% = 0\%$, $B\% = 100\%$ and their full share in the electricity fuel mix is added in the indigenous total.

However, when fuel Fi,j,k is imported by $A\%$ being $0\% > A\% > 100\%$, then $B\% = 100\% - A\%$ and $0\% > B\% > 100\%$ as well. If this fuel Fi,j,k is used outside the electricity sector in other sectors of the economy, then it is very difficult to identify if the imported $A\%$ or the indigenous $B\%$ or which mix of them has been used in the electricity sector. Since no specific data are available with regards to this issue the current study considers that the electricity sector consumes proportionately from imported and indigenous amounts. Hence for these fuels $A\%$ of their share in the electricity

Table 1
Types of fuels taken into account.

Fi	$i = 1$	$i = 2$	$i = 3$	$i = 4$	$i = 5$	$i = 6$	$i = 7$	$i = 8$	$i = 9$	$i = 10$
	Hard coal	Brown coal	Natural gas	Oil	Derived gas	Industrial waste	Hydro	Wind	Biomass	Nuclear